COMPONENT SELECTION, ACCELERATED TESTING, AND IMPROVED MODELING OF AMTEC SYSTEMS FOR SPACE POWER

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## ABSTRACT

Alkali metal thermal to electric converter (AMTEC) designs for space power are numerous, but selection of materials for construction of long-lived AMTEC devices has been limited to electrodes, current collectors, and the solid electrolyte. AMTEC devices with lifetimes greater than 5 years require careful selection and life testing of all hot-side components. The likely selection of a remote condensed design for initial flight test and probable use with a GPHS in AMTEC powered outer planet probes requires the device to be constructed to tolerate T > 1 150K, as well as exposure to $Na_{(g)}$, and $Na_{(liq)}$ on the high pressure side. The temperatures involved make critical high strength and chemical resistance to Na containing $Na_2O$. Selection among materials which can be worked should not be driven by ease of fabricability, as high temperature stability is the critical issue. These concepts drive the selection of Mo alloys for $Na_{(liq)}$ containment in AMTEC cells for T to 1150K operation, as they are significantly stronger than comparable Nb or Ta alloys, are less soluble in $Na_{(liq)}$ containing dissolved $Na_2O$, are workable compared with w alloys (which might be used for certain components), and are ductile at the T > 500K of proposed AMTEC modules in space applications. Either a wick with μm-scale pores, or au electromagnetic pump at T c 500K, with a throat dimension of about 0.1 mm to recirculate the Na working fluid, require that the volubility of structural alloys used in with high temperature $Na_{(liq)}$ must be far less than would lead to containment failure; precipitation of dissolved metal in the high temperature end of the wick or transport of dissolved metal down a temperature gradient to the electromagnetic pump, could lead to failure. The testing of AMTEC components using the same procedures of testing employed with electrode life testing: evaluation of aging phenomena via microscopic analysis at times well before failure or even microscopically detectable change; fundamental modeling using physical parameters and minimal empiricism; and verification of accelerated test procedures with comparison to normal life tests, is the only viable means to a long-lived AMTEC module for near term, long-life use. Some compromises of system design to accommodate materials life issues may also be required. For example, a favorable design includes hot feedthroughs to series/parallel connection of the individual AMTEC modules. Feedthrough Temperature may be constrained by the attack of sodium vapor on hot $\alpha$-$Al_2O_3$ at high temperature; however, a feedthrough slightly cooler than the hot side temperature may int reduce negligible thermal losses and greatly increase life. These sorts of compromises lead to model complexity. Evaluation of laboratory cell performance has already invalidated the assumptions of early syst cms studies. For example, high rate performance was found to reduce radiative losses in a 13% efficient cell where an ideal reflective film of sodium had not formed at lower current densities on all surfaces. These complications hinder unverified extrapolation from simple models, but experimental evaluation of phenomena observed in AMTEC cells allows the development of more realistic, if somewhat complex models. The research described in this paper was performed by the Jet Propulsion Laboratory, California Institute of Technology, and was supported by the National Aeronautics and Space Administration.